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Research Article

Mechanical, Thermal, and Ablative Properties of Silica, Zirconia, and Titania Modified Carbon-Phenol Ablative Composites

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The effect of nanozirconia, nanotitania, and fumed silica on the mechanical, thermal, and ablation behaviour of carbon-phenolic (C-Ph) composites is investigated. The inorganic nanofillers at different loading percentage are used to prepare nano-C-Ph panels by the compression moulding technique. The dispersion of nanofillers is confirmed through SEM analysis. After manufacturing of C-Ph laminates, the mechanical properties such as tensile strength and hardness are evaluated and the effect of these fillers is investigated. Thermal conductivity, thermal erosion, and back wall temperatures were measured to understand the thermal and ablation behaviour of nano-C-Ph laminates. Additionally, the ablation mechanism is analysed by performing SEM analysis of partially and fully burnt composite laminates. The erosion resistance and burnout time of zirconia-C-Ph panels significantly improved with increase in filler loading percentage; however, the back wall temperature rises with filler loading. Titania-filled C-Ph panels show a better control over the back wall temperature but with a poor erosion control. Silica-filled composite panels have shown a balance between decreased back wall temperature with a reasonable erosion rate and burnout time.

1. Introduction

Ablative materials represent the conventional approach towards thermal protection to aerodynamic structures, component rocket, and aircraft engines from aerodynamic heating [1]. Most of the ablative materials are fiber-reinforced composites. Thermoset resins such as epoxies, bismaleimides, polyimides, polyarylacetylene, cyanate ester, and phenolic are used as matrices for ablative materials [2–4]. These resins possess a high thermal stability and high char yield. However, phenolic resin, especially resol type, is still used mostly due to their superior mechanical strength, dimensional stability, high resistance against various solvents, good heat resistance, excellent ablative properties, and a high char yield (60%) [5, 6]. Moreover, low cost is the vital characteristic of phenolic resin, which enables them to be used so widely for these applications. The formation of carbonaceous "char" during ablation radiates the heat and acts as an insulating layer to the bulk material [7, 8]. Reinforcements used for these composites must provide "char" with mechanical stability. Carbon fibers have been extensively used as reinforcement in composites for thermal protection due to their high dimensional stability, nonflammability, low density, and excellent mechanical properties [9]. Composite materials based on phenolic resins and carbon fibers (C-Ph) were used by NASA as standard